

TITLE OF THE INVENTION

LINEAR COMPRESSOR AND APPARATUS TO CONTROL THE SAME

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims the benefit of Korean Patent Application No. 2003-53779, filed August 4, 2003 in the Korean Intellectual Property Office, the disclosure of which is incorporated herein by reference.

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0002] The present invention relates, in general, to linear compressors and, more particularly, to a linear compressor in which a piston is linearly reciprocated by a linear motor, and an apparatus to control the linear compressor.

2. Description of the Related Art

[0003] Generally, since a reciprocating compressor converts a rotary motion of a motor into a linear motion to operate a piston, an energy loss occurs during a motion conversion procedure, thus deteriorating an energy efficiency thereof. Different from that of the reciprocating compressor, a linear compressor uses a linear motor in which a mover linearly reciprocates, so that a linear motion of a piston is directly connected to the linear motion of the mover of the linear motor without a procedure to convert a rotary motion into the linear motion, thus reducing an energy loss therefrom. As a result, the linear compressor is more efficient than that of the reciprocating compressor.

[0004] In the linear compressor, a maximum efficiency may be obtained when a resonance frequency of the linear compressor and a frequency of a drive current supplied to the linear motor are equal. However, since the resonance frequency actually varies due to certain causes, such as a load fluctuation of a piston, a scheme is required to cause the frequency of the drive current to be equal to the resonance frequency of the linear compressor.

SUMMARY OF THE INVENTION

[0005] Accordingly, it is an aspect of the present invention to provide a linear compressor and apparatus to control the linear compressor, which allows a frequency of a drive current of the linear compressor supplied to a drive motor to be synchronized with a resonance frequency varying according to a load fluctuation, in real time, thus obtaining a maximum efficiency of the linear compressor.

[0006] Additional aspects and/or advantages of the invention will be set forth in part in the description which follows and, in part, will be obvious from the description, or may be learned by practice of the invention.

[0007] The above and/or other aspects are achieved by providing a linear compressor including a drive motor and a piston reciprocating by the drive motor. A control unit generates a reference current having a phase difference of 90° and an equal frequency with respect to a displacement waveform of the piston, and controls a drive current supplied to the drive motor to synchronize with a resonance frequency of the piston by synchronizing the drive current with the reference current.

[0008] The above and/or other aspects are achieved by providing an apparatus controlling a linear compressor including a displacement/speed detecting unit, an amplitude control unit, a phase control unit and a current control unit. The displacement/speed detecting unit generates at least one of a displacement waveform and a speed waveform of a piston. The amplitude control unit sets a maximum amplitude of a drive current required to control a drive motor so that top and bottom dead centers of the piston, respectively, satisfy top and bottom dead center commands received from an outside of the linear compressor. The phase control unit generates a reference waveform satisfying a condition in which the reference waveform has a phase difference of 90° and an equal frequency with respect to the displacement waveform of the piston, or a condition in which the reference waveform has both a phase and a frequency equal to those of the speed waveform of the piston.

[0009] The current control unit generates a reference current according to amplitude information and phase and frequency information provided from the amplitude control unit and

the phase control unit, respectively, and controls the drive current supplied to the drive motor to synchronize with the reference current.

[0010] A driving force generated by the drive motor (linear motor) of the linear compressor is proportional to a product of a back electromotive force of the drive motor and the drive current supplied to the drive motor. Therefore, when a drive current with a phase equal to that of the back electromotive force is supplied to the drive motor, the linear compressor may be operated at the maximum efficiency. In a case in which the linear compressor is driven at a frequency (for example, 60Hz or 50Hz) equal to that of AC power by using a switching device, such as a triac, and a phase control scheme, a resonance frequency of the linear compressor and a frequency of the AC power are equal. Therefore, when a drive current with a phase equal to that of the back electromotive force of the drive motor is supplied to the motor, the linear compressor may be operated at the maximum efficiency. When the linear compressor is driven at the resonance frequency, the drive current has a phase equal to that of the back electromotive force (or the speed) of the motor and has a phase difference of 90° compared to the displacement of the piston.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] These and/or other aspects and advantages of the invention will become apparent and more readily appreciated from the following description of the preferred embodiments, taken in conjunction with the accompanying drawings of which:

FIG. 1 is a block diagram of an apparatus to control a linear compressor, according to a first embodiment of the present invention;

FIG. 2 is a block diagram showing a control unit of the linear compressor control apparatus of FIG. 1;

FIG. 3 is a block diagram showing an amplitude control unit of the control unit of FIG. 2;

FIG. 4 is a block diagram showing a phase control unit of the control unit of FIG. 2;

FIG. 5 is a block diagram of an apparatus to control a linear compressor, according to a second embodiment of the present invention; and

FIG. 6 is a block diagram showing a phase control unit provided in the linear compressor control apparatus of FIG. 5.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0012] Reference will now be made in detail to the present preferred embodiments of the present invention, examples of which are illustrated in the accompanying drawings, wherein like reference numerals refer to like elements throughout. The embodiments are described below to explain the present invention by referring to the figures.

[0013] FIGS. 1 to 4 are views showing a linear compressor and apparatus to control the linear compressor, according to a first embodiment of the present invention, which illustrates a case in which a displacement and a speed of a piston are detected through a displacement sensor, and a mechanical resonance frequency of the linear compressor is obtained using the detected displacement and the detected speed.

[0014] FIG. 1 is a block diagram of an apparatus controlling a linear compressor, according to the first embodiment of the present invention. As shown in FIG. 1, a converter 104 converts alternating current (AC) power supplied from an AC power source 102 into direct current (DC) power. An inverter 106 connected to the converter 104 through a DC coupling capacitor 108 generates AC power with a variable voltage level and/or a variable frequency required to drive a linear motor 110.

[0015] An input terminal and an output terminal of the inverter 106 are connected to a voltage detecting unit 118 and a current detecting unit 112, respectively. The voltage detecting unit 118 detects a level of a DC voltage supplied to the inverter 106. The current detecting unit 112 detects a drive current flowing through the linear motor 110.

[0016] A displacement/speed of the piston is obtained by a displacement sensor 120 and a displacement/speed detecting unit 116. The displacement sensor 120 detects a displacement of a mover (or piston) of the linear motor 110. The displacement/speed detecting unit 116 detects a displacement waveform and a movement speed waveform of a reciprocating piston based on results detected by the displacement sensor 120.

[0017] A control unit 114 controls a switching operation of the inverter 106 to allow the drive current supplied to the linear motor 110 to synchronize with a resonance frequency of the linear

compressor using the results detected by the current detecting unit 112, the voltage detecting unit 118 and the displacement/speed detecting unit 116.

[0018] FIG. 2 is a block diagram showing the control unit 114 of the linear compressor control apparatus of FIG. 1. As shown in FIG. 2, the control unit 114 includes a phase control unit 202, an amplitude control unit 206, a current command generating unit 204 and a current control unit 208. The control unit 114 controls the inverter 106 so that the inverter 106 generates a reference current, which has a frequency and a phase equal to a resonance frequency and a phase of the piston and enables top and bottom dead centers of the piston to reach target values received from an outside of the linear compressor, and allows the drive current supplied to the linear motor 110 to synchronize with the reference current.

[0019] In FIG. 2, the phase control unit 202 generates a sine wave signal that has a phase equal to that of the movement speed waveform of the piston generated by the displacement/speed detecting unit 116 and has a phase difference of 90° compared to the displacement waveform. The amplitude control unit 206 obtains a first difference between an actual top dead center of the piston detected by the displacement/speed detecting unit 116 and a commanded top dead center based on the top dead center command received from the outside of the linear compressor and a second difference between an actual bottom dead center of the piston detected by the displacement/speed detecting unit 116 and a commanded bottom dead center based on the bottom dead center command received from the outside of the linear compressor. Further, the amplitude control unit 206 sets a maximum amplitude (peak value) of the drive current supplied to the linear motor 110 to an intensity to compensate for the first and second differences. The current command generating unit 204 generates a current command signal (a reference current) having frequency information of the sine wave signal output from the phase control unit 202 and information of the maximum amplitude output from the amplitude control unit 206. While monitoring a drive current currently supplied to the linear motor 110 and detected by the current detecting unit 112, the current control unit 208 generates an inverter control signal to control the inverter 106 so that the drive current supplied to the linear motor 110 is synchronized with the frequency, the phase and the maximum amplitude of the current command signal generated by the current command generating unit 204.

[0020] FIG. 3 is a block diagram showing the amplitude control unit 206 of the control unit 114 of FIG. 2. As shown in FIG. 3, the top dead center command and the bottom dead center command, received from the outside of the linear compressor, are set in a top dead center setting unit 302 and a bottom dead center setting unit 304, respectively. A first adder 306 obtains a difference between the commanded top dead center set in the top dead center setting unit 302 and an actual top dead center of the piston detected by the displacement/speed detecting unit 116. A second adder 308 obtains a difference between the commanded bottom dead center set in the bottom dead center setting unit 304 and an actual bottom dead center of the piston detected by the displacement/speed detecting unit 116. An amplitude setting unit 310 sets the maximum amplitude of the sine wave signal to compensate for the differences between the commanded top dead center and the actual top dead center and between the commanded bottom dead center and the actual bottom dead center, which are obtained by the first and second adders 306 and 308, respectively. The maximum amplitude set by the amplitude setting unit 310 is provided to the current command generating unit 204, and later used as maximum amplitude information of the current command signal that controls the drive current supplied to the linear motor 110.

[0021] FIG. 4 is a block diagram showing the phase control unit 202 of the control unit 114 of FIG. 2. As shown in FIG. 4, a phase comparing unit 402 compares phases of signals, respectively, output from the displacement/speed detecting unit 116 and a voltage controlled oscillating unit 404 with each other, and generates a voltage signal with an intensity (i.e., a magnitude) proportional to a phase difference therebetween. The voltage controlled oscillating unit 404 outputs a sine wave signal with a frequency varying in proportion to the intensity of the voltage signal output from the phase comparing unit 402. A phase difference generating unit 406 shifts a phase of the sine wave signal output from the voltage controlled oscillating unit 404 by 90°. The drive current must have a phase difference of 90° compared to the displacement waveform of the piston, or have a phase equal to that of the movement speed waveform of the piston. Therefore, the phase of the displacement waveform of the piston detected through the displacement sensor 120 is shifted by 90° by the phase difference generating unit 406 to be equal to that of the movement speed waveform. The sine wave signal generated by the phase control unit 202 is provided to the current command generating unit 204 and used as frequency and phase information of the current command signal.

[0022] That is, the current command generating unit 204 of the control unit 114 determines the frequency, the phase and the maximum amplitude of the current command signal by obtaining information of the phase and the maximum amplitude through the phase control unit 202 and amplitude control unit 206, thus generating the current command signal. The current control unit 208 generates an inverter control signal to control a switching operation of the inverter 106 so that the drive current supplied to the linear motor 110 is synchronized with the phase, the frequency and the maximum amplitude of the current command signal generated by the current command generating unit 204.

[0023] FIGS. 5 and 6 are views showing an apparatus controlling a linear compressor, according to a second embodiment of the present invention, which illustrates a case in which a displacement and a speed of a mover of a drive motor (linear motor) are indirectly detected using electrical characteristic values of the linear motor instead of using a displacement sensor, and a mechanical resonance frequency of the linear compressor is obtained using the indirectly detected displacement and the speed.

[0024] FIG. 5 is a block diagram of an apparatus controlling a linear compressor, according to a second embodiment of the present invention. As shown in FIG. 5, a displacement/speed detecting unit 502 generates displacement/speed waveforms of a piston using a drive current detected by a current detecting unit 112, a DC voltage supplied to an inverter 106 and detected by a voltage detecting unit 118, and electrical characteristic values of a linear motor 110. As is described above, a control unit 514 controls the drive current supplied to the linear motor 110 using the displacement/speed waveforms of the piston detected by the displacement/speed detecting unit 502.

[0025] In the control apparatus of FIG. 5, since the speed waveform of the piston is generated using the electrical characteristic values of the linear motor 110 instead of using a displacement sensor, a construction of a phase control unit 610 includable in the control unit 514 varies from the phase control unit 202 of the first embodiment of the present invention and is shown in FIG. 6. FIG. 6 is a block diagram showing a phase control unit 610 provided in the linear compressor control apparatus of FIG. 5. As shown in FIG. 6, since a speed waveform of the piston is directly detected using the electrical characteristic values of the linear motor 110,

the phase control unit 610 does not require a phase difference generating unit 406 of the first embodiment of the present invention as shown in FIG. 4.

[0026] As is apparent from the above description, a linear compressor and an apparatus controlling the linear compressor are provided, which allow a frequency of a drive current supplied to a drive motor to synchronize with a resonance frequency varying according to a load fluctuation, in real time, thus obtaining a maximum efficiency of the linear compressor.

[0027] Although a few embodiments of the present invention have been shown and described, it would be appreciated by those skilled in the art that changes may be made in these embodiments without departing from the principles and spirit of the invention, the scope of which is defined in the claims and their equivalents.